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(12) **Patent Application:** (11) **CA 2093898**

(54) INTERMITTENT COATING APPARATUS AND METHOD

(54) APPAREIL ET METHODE DE REVETEMENT INTERMITTENT

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ABSTRACT:

INTERMITTENT COATING APPARATUS AND METHOD
ABSTRACT OF THE DISCLOSURE
Coating apparatus comprises a coating head (12) for positioning over a substrate (18) to be coated. The coating head (12) includes a reservoir (20) for holding an amount of slurry (22) to be applied to the substrate (18). The reservoir (20) is provided with a slurry discharge opening (38) for discharging slurry onto the substrate

(18). A closure member (24) is provided for selectively opening and closing the slurry discharge opening (38). The apparatus further includes means for intermittently raising and lowering the coating head (12) relative to the substrate (18) in synchronism with the opening and closing of the slurry discharge opening (38). In a particular embodiment, the raising and lowering means comprises a cam-driven rocking frame (14) on which the coating head
(12) is mounted. A coating method in which the coating head (12) is raised upon closing of the slurry discharge opening (38) is also provided.

CLAIMS: Show all claims

*** Note: Data on abstracts and claims is shown in the official language in which it was submitted.

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Patent Document Number 2093898 :

INTERMITTENT COATING APPARATUS AND METHOD

APPAREIL ET METHODE DE REVETEMENT INTERMITTENT

CLAIMS:

EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A coating apparatus comprising: a coating head for positioning over a moving substrate web to be coated, said coating head including a reservoir for holding an amount of slurry to be applied to said substrate and said reservoir being provided with a slurry discharge opening for discharging slurry onto said substrate for coating the substrate with the slurry; a closure member for selectively opening and closing said slurry discharge opening; and means for intermittently raising and lowering the coating head relative to said substrate in synchronism with the opening and closing of said slurry discharge opening.

2. The apparatus according to claim 1, wherein said
means for intermittently raising and lowering the coating head relative to said substrate comprises a cam-driven rocking frame on which said coating head is mounted.

3. The apparatus according to claim 2, wherein said
closure member is curved in cross section and forms the bottom and one side wall of said reservoir, said reservoir having an opposite side wall, said slurry discharge opening being defined between said closure member and said opposite side wall and said closure member being movable relative to said opposite side wall to open and close said slurry discharge opening.

4. The apparatus according to claim 3, wherein said
closure member is movable relative to said opposite side wall about a pivotal axis located at the centre of curvature of said closure member.

5. The apparatus according to claim 1, further

comprising a roller having a support surface for said substrate web below said coating head for supporting the substrate to be coated thereon.

6. The apparatus according to claim 5, further
comprising a scraper blade which is operative on said substrate support surface for cleaning said surface.

7. The apparatus according to claim 5, further
comprising drive means for said roller.

8. The apparatus according to claim 5, further
comprising a pair of spaced sliding supports on said coating head which ride on said support roller outboard of the web.

9. The apparatus according to claim 2, wherein said
closure member is connected to a cam operated rocking lever for effecting said movement of said closure member for opening and closing said slurry discharge opening.

10. The apparatus according to claim 3, further
comprising a doctoring blade on said opposite side wall adjacent said slurry discharge opening.

11. Coating apparatus comprising a coating head for
positioning over a moving substrate web to be coated, said coating head including a reservoir for holding an amount of slurry to be applied to said substrate, said reservoir being provided with a slurry discharge opening for discharging slurry onto said substrate for coating the substrate with the slurry and a closure member for selectively opening and closing said slurry discharge opening, wherein said coating head is vertically movable relative to said substrate to interrupt the coating of the substrate when said slurry discharge opening is closed.

12. The apparatus according to claim 11, wherein said
closure member is curved in cross section and forms the bottom and one side wall of said reservoir, said reservoir having an opposite side wall, said slurry discharge opening being defined between said closure member and said opposite side wall and said closure member being movable relative to said opposite side wall to open and close said slurry discharge opening.

13. The apparatus according to claim 12, wherein said
closure member is movable relative to said opposite side wall about a pivotal axis located at the centre of curvature of said closure member.

14. The apparatus according to claim 11, further
comprising a roller having a surface for supporting said substrate web below said coating head for supporting the substrate to be coated thereon,

15. The apparatus according to claim 14, further
comprising a pair of spaced sliding supports on said coating head which ride on said support roller outboard of the web.

16. The apparatus according to claim 13, further comprising a scraper blade which is operative on said substrate support surface for cleaning said surface.

17. The apparatus according to claim 16, further comprising drive means for said roller.

18. The apparatus according to claim 11, wherein said coating head is mounted on a horizontal frame which is pivotally supported at one end and supported by a first cam on an opposite end, whereby said opposite end is cyclically raised and lowered by rotation of said first cam to raise and lower said coating head vertically relative to said substrate.

19. The apparatus according to claim 18, wherein said closure member is provided with a lever thereon, the lever, at one end, being pivotally supported at said centre of curvature of the closure member and supported by a second cam at its free end, whereby said lever is cyclically raised and lowered by rotation of said second cam to effect said opening and closing of said slurry discharge opening.

20. A method of coating a substrate, which is moving at a predetermined linear velocity, to provide a coating on the substrate which has coated areas interrupted by uncoated areas by means of a coating head containing an amount of slurry and provided with a slurry discharge opening therein, comprising the steps of: locating the coating head above said moving substrate; opening said slurry discharge opening to discharge a metered amount of slurry onto said moving substrate for coating the substrate with the slurry: closing said slurry discharge opening and raising the coating head relative to the substrate to interrupt the coating of the substrate.

21. The method according to claim 20, further comprising the steps of lowering said coating head relative to said moving substrate and opening said slurry discharge orifice to resume the coating of said substrate.

22. The method according to claim 21, further comprising the step of supporting the substrate from underneath by means of a roller and driving the roller at a tangential velocity which coincides with the linear velocity of the substrate to eliminate relative movement between said substrate and said roller.

23. The method according to claim 22, further comprising the step of cleaning said roller surface by means of a scraper blade which is operative on said roller.

24. The method according to claim 23, further comprising the step of slidingly supporting said coating head on said roller for counteracting inaccuracies in coating thickness due to corresponding inaccuracies in rotational runout of the roller.

25. A battery having electrodes coated using the apparatus according to claim 1 or 11.

26. A battery having electrodes coated using the method according to claim 20.

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INTERMITTENT COATING APPARATUS AND METHOD

FIELD OF THE INVENTION

This invention relates to a method and apparatus for providing intermittent deposits of a liquid slurry onto a moving substrate to provide intermittent coatings on the substrate which are separated by uncoated segments.

BACKGROUND OF THE INVENTION

The electrodes of rechargeable lithium or lithium ion cells can be thin metallic foils which are coated with the appropriate active materials on one or both surfaces of the foil. In the manufacture of electrode stock for such cells, it is desirable that the electrodes be manufactured in long strips having coated segments separated by uncoated segments. The uncoated segments provide the required exposed foil for attachment of metallic tabs for electric contact with the electrodes and the external cell contacts. In addition, for cells of prismatic design, the uncoated segments provide a location where the electrodes can be folded.

In order to obtain such uncoated segments, methods such as substrate masking or subsequent coating removal, in which the coating is removed by chemical or mechanical means, have been applied. These methods, however, are considered to be unacceptable in that they can result in substrate damage and/or material contamination. These methods also reduce overall production efficiency as they require additional processes and equipment.

A method for achieving intermittent coating of a substrate in which a slurry discharge opening is

intermittently opened or closed, to directly obtain the intermittent coatings, is described in published Japanese patent application No. 184069/1989. However, this method was found to produce unacceptable results with some slurries, in the production of crisp, abrupt termination edges of the deposited coating segment. This is due primarily to the formation of a meniscus of slurry on the downstream facing side of the doctoring element. Effective stopping, or gating of the flow of slurry onto the substrate is then inhibited in that the volume of slurry within the meniscus must be expended before the coating is completely terminated. This results in a termination edge which is of irregular and feathered form.

It is an object of the present invention to alleviate the above-mentioned difficulty.

SUMMARY OF THE INVENTION

According to the invention, there is provided a coating apparatus comprising a coating head for positioning over a moving substrate web to be coated, said coating head including a reservoir for holding an amount of slurry to be applied to said substrate and said reservoir being provided with a slurry discharge opening for discharging slurry onto said substrate for coating the substrate with the slurry; a closure member for selectively opening and closing said slurry discharge opening; and means for intermittently raising and lowering the coating head relative to said substrate in synchronism with the opening and closing of said slurry discharge opening.

The means for intermittently raising and lowering the coating head relative to the substrate may

comprise a cam-driven rocking frame on which the coating head is mounted.

Also according to the invention, there is provided coating apparatus comprising a coating head for positioning over a moving substrate web to be coated, said coating head including a reservoir for holding an amount of slurry to be applied to said substrate, said reservoir being provided with a slurry discharge opening for discharging slurry onto said substrate for coating the substrate with the slurry and a closure member for selectively opening and closing said slurry discharge opening, wherein said coating head is vertically movable relative to said substrate to interrupt the coating of the substrate when said slurry discharge opening is closed.

Further according to the invention, there is provided a method of coating a substrate, which is moving at a predetermined linear velocity, to provide a coating on the substrate, which has coated areas interrupted by uncoated areas, by means of a coating head containing an amount of slurry and provided with a slurry discharge opening therein, comprising the steps of locating the coating head above said moving substrate; opening said slurry discharge opening to discharge slurry onto said moving substrate for coating the substrate with the slurry; closing said slurry discharge opening and raising the coating head relative to the substrate to interrupt the coating of the substrate.

Further objects and advantages of the invention will become apparent from the description of a preferred embodiment of the invention below.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a three-dimensional view of one embodiment of a coating apparatus according to the invention;

Figure 2 is a schematical diagram of the apparatus of Figure 1, showing the apparatus in part sectional side view to better illustrate the working of the components thereof;

Figure 3 is an enlarged view to more clearly illustrate an area in the vicinity of a slurry discharge opening of the apparatus of Figure 2; and

Figures 4A and B, respectively, illustrate an application in which the method of the invention is employed and an application in which it is not employed.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring to the drawings, reference numeral 10 generally indicates a coating apparatus comprising a coating head 12, a support frame 14 for the coating head 12 and a backing roller 16 (not shown in Figure 1) for the substrate being coated, which in the present example is a web 18 of metal foil.

The coating head 12 has a reservoir 20 for containing a quantity of slurry 22 for coating the web 18. The reservoir 20 is defined between a curved member 24 forming the base and one sidewall of the reservoir 20 and an essentially flat member 26 forming the opposite sidewall of the reservoir 20. The lateral sides of the reservoir 20 are formed by a pair of flat members 28 (not shown in Figure 2).

The curved member 24 is movable relative to the flat member 26 about a pivotal axis 30 which is located at the centre of curvature of the curved member 24, as shown in Figure 2. A lever 32 is connected to the curved member 24 and is in contact with a cam 34 which is rotatable on a shaft 36. Rotation of the cam 34 raises and lowers the lever 32 which causes pivotal movement of the curved member 24 relative to the member 26 between a first limiting position, in which a slurry discharge opening 38 is defined between the members 24 and 26 at the base of the reservoir 20, as shown in Figure 2, and a second limiting position in which the opening 38 is closed (not shown).

Torsional springs 39 are provided at opposite ends of the pivotal axis 30 which act about the axis 30 to exert a desired closing force on the curved member 24.

The frame 14 on which the coating head 12 is mounted is supported at three points, being a single pivoting support 40 about the shaft 36 at one end of the frame 14, and a pair of spaced sliding supports 42, which ride on the backing roller 16 outboard of the web 18, at the opposite end of the frame 14.

A further cam 41, operative on the frame 14 opposite to the pivotal support 40, is provided on a shaft 43. Rotation of the shaft 43 intermittently raises and lowers the coating head 12 through the action of the cam 41 on the frame 14.

The vertical gap 44 (see Figure 3) defined as the distance between the lower edge of the member 26 and the web 18 is manually set by means of a pair of calibrated fine pitch screw thread adjusters 46. The

deposition thickness of the slurry 22 is controlled by adjustment of the gap 44. As shown, the lower end of the member 26 is provided with a doctoring blade 47 thereon for doctoring the slurry deposited onto the web 18 to the desired thickness. More precisely, the gap 44 is defined between the lower end of the doctoring blade 47 and the web 18.

One or more filler tubes 48 are provided for feeding slurry 22 to the reservoir 20. Dependent on slurry properties and the ramifications of having gas entrained in the slurry, the filler tube(s) 48 may extend downward below the head level of the slurry 22, as shown in broken lines in Figure 2. A high level sensor 50 and a low level sensor 52 are provided for controlling the head level of the slurry 22 between upper and lower control limits. In Figure 2, non-contacting optic sensors are shown.

A blade 54 is held against the backing roller 16 to remove particulate material therefrom. A catch tray 56 is provided beneath the roller 16 for catching any particulate material removed from the roller 16 by the blade 54. The coating apparatus 10 also includes drive means (not shown) for driving the backing roller 16 at a tangential velocity equal to the linear velocity of the web 18, which is moved along by suitable means (not shown) in a direction from left to right, as shown in Figure 2.

OPERATION

During a coating operation the web 18 is moved at a predetermined constant speed supported by the backing roller 16, which, as stated above, is driven at a tangential velocity equal to the linear velocity of the web 18 so that there is no relative slippage at the

interface between the roller 16 and the surface of the web 18. This counteracts abrasive wear of the roller 16 as well as damage to the coating on the web 18. This is of particular importance when coating the second side of the web 18 during which time the coated first side of the web 18 is in contact with the roller 16.

In operation, the slurry 22 is deposited onto the web 18 through the slurry discharge opening 38 to achieve an intermittent coating pattern on the web 18 by the intermittent interruption or termination of the coating deposition. This is accomplished by the combination of two interdependent and sequenced motions. The first is a closure of the slurry discharge opening 38 by the rotational movement of the curved member 24 about the pivotal axis 30, which is effected by rotation of the cam 34 about the shaft 40, which causes a pivoting action of the lever 32 about the axis 30. The second motion is a vertical lifting of the coating head 12 from the roller 16. This is accomplished by rotation of the cam 41 on the shaft 43 which causes a pivoting action of the frame 14 about the shaft 36. In the present example, the rotation of the shafts 36 and 40 is driven by electrical servo motors, but any other suitable drive means, including pneumatic and hydraulic cylinders and motors, may be used.

The above lifting of the coating head 12 upon closure of the slurry discharge opening 38 acts to break the meniscus of slurry attached to the doctoring blade 46, thereby producing a clean termination edge.

Cyclic rotation of the cams 34 and 41 reinitiates the coating process by first lowering the coating head 12 onto the roller 16 and opening the slurry discharge opening 38.

The complete sequencing of the termination and reinitiating procedures described above are electronically controlled and are referenced to the measured travel of the web 18 so that the desired repetitive pattern is produced. The timing of the lifting of the coating head 12 relative to the closing of the slurry discharge opening 38 is important and is dependent upon the physical and chemical characteristics of the particular slurry used in each application. For example, in some applications the best results may be obtained by lifting the coating head 12 immediately upon closing of the slurry discharge opening 38 but in other applications, a short time delay between the closure of the slurry discharge opening 38 and the lifting of the coating head 12 (lift delay) produces better results. The required lift delay for a particular slurry can be ascertained by performing simple tests with the slurry in which the lift delay is varied over a range of values.

Closure arrangements, such as the linear shuttle described in Japanese patent application No. 184069/1989, can displace a considerable volume of slurry and, in doing so, exert forces which would act to drive excess slurry under the doctoring blade 47. The action of pivoting the curved member 24 about its centre of curvature, which results in the opening and closing of the slurry discharge opening 38, displaces a minimal volume of slurry 22. Also, there is no appreciable change in the head level of the slurry 22 within the reservoir 20 which simplifies the control of the sensing and replenishment of this level.

By supporting the coating head 12 on the backing roll 16 by means of the sliding supports 42, the surface of the roller 16 is used as the reference datum for the doctoring blade 46. With this arrangement, the potential detrimental effect of inaccuracies in rotational runout of

the roller 16 on deposition thickness control is counteracted.

The lifting of the coating head 12 further results in a self cleaning function in that oversize particles within the slurry which may become trapped in the gap 44 will be released. The detrimental effects of trapped particles on the coating is then generally limited to a single deposition segment only.

In order to coat the opposite side of the web 18, it is repositioned and fed through the coating apparatus 10 with its opposite side facing upwards. The vertical gap 44 is adjusted to compensate for the initial coating thickness and the process is repeated. Alignment of the coated and uncoated areas of the two opposing sides of the web 18 is maintained by a photosensor (not shown) which detects the leading edges of the coated and uncoated areas of the first side. The detection then triggers the electronic control of the termination/reinitiation processes.

One example of an application of the invention and a comparison with a method in which the coating head is not raised is described below with reference to Figures 4A and B of the drawings.

Example

Anode electrode coatings to be used in cylindrically wound lithium batteries were made. A slurry was prepared by blending active anode material and a binder in a carrier solvent. The active material used was a coke-like carbon powder, 20 micrometers in size, known as mesocarbon microbeads. The binder used was polyvinylidene fluoride. The solvent used was n-methyl pyrrolidone. The substrate coated was a 10-micrometer-

thick copper foil. The coating was first applied using the method of the present invention in which the coating head is lifted at the termination of the coating and as a comparative example, the procedure was repeated but without lifting the coating head at the termination of the coating.

The result obtained when the coating head is lifted at the termination of the coating is shown in Figure 4A and the result obtained when the head is not lifted is shown in Figure 4B. In the drawings, the direction of travel of the web 18 is from left to right. The edge at the initiation of a coating (initiation edge) is indicated by reference numeral 60 and the edge at the termination of a coating (termination edge) is indicated by reference numeral 62. The point at which the slurry discharge opening 38 is closed is indicated by reference numeral 64. The distance X3 represents the coated anode length or active anode length. The distance X1 is the uncoated length for attaching a current collecting tab to the electrode and X2 is the distance over which the coating irregularities extend at the termination edge 62. In this example, X3 was set to be approximately 50 cm and X1 was set to be approximately 5 cm so that the resulting anode would be suitable for use in a 4/3 A size battery.

As can be seen from Figure 4B, where the coating head is not lifted at the termination of the coating, the termination edge 62 has a ragged or feathered form and the distance X2 over which the irregularities extend was found to be almost 3 mm long. With reference to Figure 4A, where the coating head is lifted, the termination edge 62 is smooth and the length X2 was found to be less than 1 mm.